

DOCUMENT RESUME

ED 406 173

SE 059 837

AUTHOR Gardiner, Peter G.; Farragher, Pierce
TITLE The Quantity and Quality of Biology Laboratory Work
in British Columbia High Schools.
PUB DATE 23 Mar 97
NOTE 23p.; Paper presented at the Annual Meeting of the
National Association for Research in Science Teaching
(70th, Oak Brook, IL, March 23, 1997).
PUB TYPE Reports - Research/Technical (143) --
Speeches/Conference Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Academic Achievement; *Biology; Educational
Strategies; Foreign Countries; High Schools;
Laboratory Equipment; *Science Curriculum; *Science
Experiments; Science Laboratories; Teaching
Methods
IDENTIFIERS British Columbia

ABSTRACT

The purpose of this study was to survey the quantity and quality of laboratory work conducted by Grade 11 and 12 biology students in British Columbia High Schools, to analyze student performance on laboratory based questions on Provincial examinations, and to examine the curriculum for recommended laboratory work. Examination and curriculum data were extracted from Ministry of Education documents. Survey data were used to generate statistics on school demographics, teachers, laboratory work, use of technology, and constraints of the provincial curriculum and examination. Findings indicate that the frequency of laboratory work was low overall with quantitative activities much less frequent than qualitative, and laboratory exercises being confirmatory rather than investigative. Although laboratories were equipped adequately, teachers indicated that the curriculum and provincial examination limit the scope for an inquiry-based course. An analysis of examination results showed that the frequency and type of laboratory work had no effect on scores on lab-based questions. Analysis revealed that fewer laboratory activities are being conducted than are recommended in the course outline. Contains 14 references.
(RH)

* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *

THE QUANTITY AND QUALITY OF BIOLOGY LABORATORY WORK IN BRITISH COLUMBIA HIGH SCHOOLS

PERMISSION TO REPRODUCE AND
DISSEMINATE THIS MATERIAL
HAS BEEN GRANTED BY

P. G. Gardiner

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

This document has been reproduced as
received from the person or organization
originating it

☐ Minor changes have been made to
improve reproduction quality

• Points of view or opinions stated in this
document do not necessarily represent
official OERI position or policy

Peter G Gardiner
Biology Dept.
St. Michaels University School
Victoria, British Columbia
Canada
pgardine@smus.bc.ca

Pierce Farragher
Dept. of Social and Natural Sciences
University of Victoria
British Columbia
Canada

A paper presented at the National Association for Research in Science Teaching (NARST)
Annual Conference in Chicago, Illinois, March 23, 1997

BEST COPY AVAILABLE

Abstract

The purpose of this research was to survey the quantity and quality of laboratory work conducted by Grade 11 and 12 Biology students in British Columbia High Schools, to analyze student performance on laboratory based questions on Provincial examinations, and to examine the curriculum for recommended laboratory work. A pilot survey was used to produce a valid survey instrument that identified teachers' use of laboratory activities in Biology 11 and 12. Examination and curriculum data were extracted from Ministry of Education documents. Survey data were used to generate statistics on school demographics, teachers, laboratory work, use of technology and constraints of the provincial curriculum and examination.

The frequency of laboratory work was low overall, with quantitative activities much less frequent than qualitative. Most laboratory exercises were confirmatory rather than investigative, and critical thinking, and formulating hypotheses was rarely expected of the students. Many teachers reported that simulations of laboratory exercises and computer-based data collection were rarely or never used. Although laboratories are equipped adequately, teachers indicated that the curriculum and provincial examination limit the scope for an inquiry-based course. An analysis of provincial examination results showed that the frequency and type of laboratory work had no effect on scores on lab-based questions. An analysis of the frequency and type of laboratory activities recommended in the syllabus was conducted and revealed that fewer laboratory activities are being conducted than are recommended in the course outline.

This study demonstrates that while the current philosophy of many teachers of science supports an investigative, hands on, minds on, authentic learning experience, little change in classroom practice has occurred in British Columbia schools.

Introduction

The education system in the province of British Columbia has, in recent years, undergone significant upheaval in terms of the perceived need for change. The 'Year 2000' document (1990) on educational reform was the primary driving force behind changes in philosophy, course content, delivery style, and focus. Similarly, the National Committee on Science Education Standards and Assessment (1992) stated that "school science education must reflect science as it is practiced".

Biological science, in common with physical science, is facing the dilemma of information overload. New material is available almost daily and teachers struggle to understand it and to update their knowledge. In addition, a common complaint by teachers is that, in senior science courses, there is too much material to cover in too little time. Much of the problem in British Columbia seems to be associated with the Provincial examination. Students are required to write an external examination in all approved Grade 12 subjects except those which have been locally developed. This puts pressure on the students and the teachers because of the time spent on examination preparation, rather than understanding science. The consequence of this seems to be that, at the Grade 12 level, much of the investigative aspect of science has disappeared or is reduced to a minimum. Those few laboratory exercises that have been retained seem to focus on confirmation rather than on investigation and data interpretation. This research focuses on this dilemma and on its effects on teaching methodology and student performance on laboratory based questions.

Throughout its history, and particularly in the last two decades, science teaching has stressed laboratory instruction. The average textbook has laboratory activities amounting to approximately 40 percent of the curriculum. Still less than half of all science teachers regularly use laboratory activities, and 25 percent report they never, or no more than once a month, use laboratory activities (Hurd, Bybee, Kahle & Yeager 1980).

The current philosophy of teaching science is an investigative, 'hands on, minds on and authentic learning experience. Discussion with teachers in the province has indicated that, despite the philosophical direction, little real change in classroom practice has occurred. It is clearly impossible for teachers to know everything about the discipline and yet traditional roles of teaching with the student as passive receiver rather than active participant, continues in schools (Miller, 1995).

Research is lacking in Canadian schools in assessing the laboratory practice of teachers in terms of the quantity and nature of laboratory work performed by their students at the senior level.

Purpose

Research has shown that there has been some disagreement over the value of the science laboratory classroom (Tamir, 1989; Lehman 1989). Much discussion about the teaching of science today revolves around curriculum reform and includes the content of high school courses, the development of science process skills, and by some, the constructivist approach. Supporting the constructivist perspective Tobin (1990) states that constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of what they are learning. Laboratory activities appeal as a way of allowing students to learn with understanding. Hands on science

teaching has been widely promoted through text books, activities manuals, methods courses and workshops for in-service teachers; and it is the key component of student centered instruction. However, this mode of teaching is far from universally employed by teachers (Prather, 1993). Levin (1995) discusses reform in Canadian schools and concludes that secondary education is badly in need of reform and that there is not much sign that the required changes are occurring. Similarly, the literature on secondary schools gives few examples of fundamental change (Lee, Bryk & Smith, 1993).

In the report, "Science Assessment in British Columbia Schools" (1991) it was concluded that secondary students are not provided with enough opportunities to be engaged in problem solving situations where they are expected to use materials to investigate a problem and speculate about the results of their inquiry. One recommendation from the assessment was that students should be given more opportunity to generate questions and seek answers from their own investigations. No specific survey has been conducted on student performance or teachers' practice in Biology for Grade 11 and 12. Performance for Grade 12 students is judged on their scores on the provincial examination combined with a school assessment. If there is little laboratory work being carried out does this have an effect on students' understanding of science and on provincial examination scores - especially on laboratory based questions? If there is insufficient laboratory work being conducted in the schools, is this a function of the course content and the time required to teach it or are there other factors at work ? This study examines such relationships. In addition, scores on laboratory questions on the provincial examination were examined to determine whether the frequency of laboratory work influenced performance.

In discussion with Biology teachers at the marking sessions for the provincial examinations, it was a common complaint that there was not sufficient time to adequately cover the course material for Grade 12 Biology. The question was then posed as to what was being deleted from the course if time was at a premium. Examination markers felt that students scored lower marks on experiment or data analysis questions than on recall questions. A poll of the teachers indicated that this was because there was no time for laboratory work. If there was not sufficient time to conduct laboratory work in Grade 12, was this also the case in Grade 11 Biology classes?

This research attempted to address the dearth of information on the teaching of senior Biology classes in Canadian schools by identifying and describing the nature of current high school laboratory practices in British Columbia. Specifically, the research sought to:

- (a) survey the quantity and quality of laboratory work being carried out in British Columbia High Schools.
- (b) compare the scores on laboratory and data analysis questions with non laboratory-based questions on the Provincial and Scholarship examinations
- (c) investigate the type and quantity of laboratory activities conducted in schools, compared with the number and type of laboratory exercises recommended in the course outline.

Research Design and Procedure.

The research method for this study was divided into three major parts:

1. The Survey

Biology teachers in British Columbia High Schools were surveyed primarily to establish the number and type of laboratory exercises conducted by teachers in the province.

In addition, the survey asked questions about school demographics, the teachers, teaching method, teacher attitudes and the use of technology in Biology classes.

The survey was mailed to Biology teachers in 248 schools in the Province¹, 216 public schools and 32 independent schools. The schools selected consisted only of those in which Grade 11 and 12 biology courses were taught. These include Secondary schools - defined as schools offering education programs for students enrolled in Grades 8 to 12 and Senior Secondary Schools, defined as those for Grade 11 and 12 students only. No distinction was made between these two categories in the survey distribution and the schools selected were representative of all of the 75 School Districts in the Province. Teachers were given the option to return the completed surveys by mail, fax or e-mail.

The survey consisted of 34 questions divided by the following sub-headings:

Demographics

In this section of the survey, teachers were asked about size of school, location of school, numbers of students, organization of the school year and hours of instruction. These are neutral questions but may have an important relationship to other aspects of the study (e.g. a relationship between size of school and number of laboratory exercises carried out by students in a school year).

The Teacher

This section of the survey elicited responses from teachers regarding years of experience, specialist training and qualifications.

¹ Public and Independent Schools Book. Province of British Columbia. 1995

Laboratory Work

This is one of the key areas of the survey in that it addresses the primary purpose of the research, viz. the quality and quantity of laboratory work in British Columbia High Schools. The questions covered topics such as: the frequency of lab exercises in Grade 11 and 12; the distinction between the number of qualitative and quantitative labs undertaken in Grade 11 and 12; the use of hypotheses and the students' understanding of scientific method; the use of technology both for instruction and computer-based data collection; and time for teaching the provincial course. Teachers' attitudes towards the courses, in terms of the content effect on a lab-based approach to teaching, were also important issues .

Assessment was touched upon with just two questions on the use of laboratory examinations and the incorporation of lab-based questions into class tests.

The final few questions dealt with the issue of the teachers' present method of instruction and attitudes towards not teaching an investigative lab-based course. Feedback on the results of the survey was offered to the teachers if they were interested, and in addition, they were asked whether they and / or their students would be willing to be interviewed in a follow up study.

The questionnaire responses were recorded and descriptive and inferential statistics generated. In addition, the responses to open-ended questions were analyzed for recurring patterns of words, phrases or sentences in order to construct assertions regarding teacher attitudes to such activities as the use of computer based data collection and individual student research.

2. Examination Analysis

Examination questions and results for the provincial and scholarship papers were analyzed in order to see whether there was any significant difference in level of achievement of Grade 12 students on laboratory based and data and analysis questions compared with non laboratory questions. For the Provincial examination multiple choice questions, mean difficulty scores were used as a measure of performance while for the written section the mean score for the questions was used. Mean scores on laboratory and non laboratory questions were compared. On the Scholarship papers, because the sample size for lab questions was so small the means were pooled and lab and non lab question grand means compared. Examination papers for January and June (1990 to 1994) were used for this study.

3. Curriculum Analysis

The laboratory requirements of the Biology 11 /12 Curriculum Guide (1990) were examined to gain information on the number of laboratory exercises which are recommended by the Province of British Columbia. These data were then sub-divided and categorized as qualitative and quantitative exercises. The Curriculum Guide was published in 1990 and was superseded by the Integrated Resource Package for Biology (1996) which was implemented in September, 1996 for Grade 11 and 1997 for Grade 12. Therefore, in addition to the analysis of the Curriculum Guide, an analysis of the IRP was conducted to establish whether there has been any significant change in the number or types of laboratory exercises and any change in the number and types of learning resources recommended to teachers.

Findings and Data Analysis.

The Survey Analysis

Two hundred and forty surveys were mailed and 108 were completed and returned representing 51 out of the 75 school districts in the province. A summary of the survey returns appears in Table 1.

Table 1
Questionnaire Distribution and Return by School Size.

School Size	No. distributed	% of distribution	No. Received	% Return by Size of school	% Received
Large (>800)	107	43.14	41	38.32	38
Medium (500-800)	68	27.42	36	52.94	33.3
Small <500	73	29.44	31	42.42	28.7
Totals	248	100	108		100

Nine percent of the schools utilized a quarter system, 55% a semester system, 31% a linear system and 5% used another timetable structure. Years of experience of the teachers returning surveys ranged from 1 to 35 years with a mean of 20 years (s.d.=17.82). The term teacher refers to those individuals who are actively teaching Biology and returned a completed survey (Table 2).

Ninety-three percent of these teachers had received specialist training in Biology with 49% holding a B.Sc. and 42% holding graduate degrees.

Table 2**The Distribution of Teachers in the Province and on the Survey by Years of Experience.**

Years of experience	<1	1-4	5-9	10-19	20+	Total
Provincial Distribution	868	6872	6013	12,223	9,236	35,212
% of total	2.47	19.5	17.08	34.71	26.23	100
Survey Distribution	0	10	15	33	49	107
% of total	0	9.35	14.02	30.84	45.79	100
Mean years of experience for the Province = 20 years (s.d.= 11.95)						
Mean years of Experience for teachers on Survey = 20 years (s.d.= 17.82)						
Average age of teachers in the Province = 42.6 years						

The survey requested information on frequency of laboratory work performed by Grade 11 and 12 students (Table 3). Of the teachers surveyed, 48% reported using <1 lab per week with 81% using ≤ 1 lab per week.

Table 3**Frequency of Quantitative and Qualitative Laboratory Work**

	Grade	Mean number of labs per year	s.d.	<5 labs per year (%)	<10 labs per year (%)
Quantitative Labs	11	4.21	3.77	81.7	93.5
	12	2.69	2.06	93.5	100
Qualitative Labs	11	14.66	8.87	10.4	46.9
	12	5.84	5.06	59.8	89.1

The number of quantitative labs in Grade 11 ranged from 0 to 20 in a year, with a mean of 4.21. (s.d.=3.77) For Grade 12 the range was 0 to 10 a year, with a mean of 2.69 (s.d.= 2.06). Ninety-four percent of teachers used ≤ 5 quantitative labs per year. For qualitative laboratory exercises in Grade 11, a mean of 14.66 labs per year was reported (s.d.=8.87) with a range of 0 - 40 labs per year. Forty-seven percent of teachers of Grade 11 students used ≤ 10 qualitative labs per year. Eighty-nine percent of teachers of Grade 12 students used ≤ 10 qualitative labs per year, with a mean of 5.84 qualitative labs per year (s.d.=5.06) and a range of 1 - 30 labs per year.. Seventy-six percent of teachers of Grade 11 described their labs as usually confirmatory rather than investigative while 83% of Grade 12 teachers indicated that their labs were usually or always confirmatory. Forty percent of teachers indicated that their labs rarely or never fostered critical thinking and 60% related that they rarely or never required students to formulate hypotheses before beginning a lab. It was thought that perhaps lab work was being replaced by technology but 82.% of teachers rarely or never used lab simulations and 96% rarely or never used computer based data collection. The most common

reason (82%) for not using technology was that teachers had no equipment. No experience was the next most common reason (37%). In terms of time to teach a lab-based course, 55% of teachers of Grade 11 indicated that they had sufficient time whereas 88% of Grade 12 teachers did not have time. Laboratory facilities were not a major constraint to teaching an inquiry course in that 67% of teachers of Grade 11 and 54% of Grade 12 teachers claimed that their labs were well enough equipped to teach this type of course. The course content is dictated by the Provincial government and the course description was a factor in limiting the scope for individual student research. Fifty-five percent of teachers agreed while 45.5% did not. Teachers of Grade 12 are subjected not only to a specific course outline but also the students write an external, final examination. This represents 40% of a student's transcript mark and teachers are therefore judged by the performance of their students. It is, therefore, not surprising that with these pressures placed upon them, 93% of the teachers of Grade 12 students related that they felt that the course outline limited the scope for teaching a lab-based course.

In terms of the provincial examination limiting the opportunities for teaching a lab-based course, 93.1% of the teachers agreed, while only 5.9% felt that it did not. Teachers have stated frequently that the course content is too large to cover in the time allowed. Therefore they find themselves hard pressed to even complete the course and cannot afford time for labs if their students are to be successful on the provincial examination. The evaluation and perception by the school administration and parents of a the teacher's effectiveness, is based on students' results on the provincial examination.

For Grade 11, 86.8% of teachers declared that their students rarely or never carry out individual lab-based research. For Grade 12 classes 98% of the teachers rarely or never used

this approach. Eighty-two percent of teachers cited that a lack of equipment was the primary reason, in spite of already indicating in a previous question that their labs were well enough equipped to teach an inquiry based course. However, 86% of teachers of Grade 11 related that they would prefer to teach an inquiry based course in preference to a traditional course. Grade 12 teachers were less enthused with 73% of teachers indicating the same preference while 27% clearly indicated that they would not. The survey results showed that 71% of the teachers described their teaching style as using primarily a lecture approach with some lab work. The three primary reasons given for not using an investigative approach were: curriculum geared towards exam preparation; no time to organize; no materials/facilities (Table 4)

The following relationships were found to be statistically significant:

- large schools perform lab work less frequently than small or medium sized schools
- laboratories are better equipped for Grade 11 than Grade 12
- Grade 11 students have time for an inquiry based course whereas Grade 12 students do not
- Grade 11 and 12 students carry out primarily confirmatory rather than investigative labs

2. Examination Analysis.

The analysis of the provincial and scholarship examinations for differences in scores between lab-based and non lab-based questions, for multiple choice and written questions, revealed that there was no significant difference in mean scores for any of the question types (Table 5; Table 6)

Table 4**Reasons Given for not Using an Investigative Approach to Biology Teaching**

<u>Reason</u>	<u>Frequency</u>
curriculum geared towards government exam preparation	38
no time to organize	35
no materials/facilities	22
limited funding	13
no experience (teacher)	6
students' background deficiencies	5
student attitude	5
needed outcome	3
no lab technicians	3
other effective ways to teach	3
understanding concepts and grasping basics	3
students need to be trained in this before Grade 11	2
no good lab guide	2
student disrespect to specimens	1

Further examination of the lab questions revealed that they were primarily recall type questions requiring little, or at best, a superficial knowledge of the scientific process. Whether students have carried out laboratory work or not, whether confirmatory or investigative, little effect on their scores on this examination was noted.

Table 5**T-tests on Multiple Choice Questions for Provincial Examinations 1990-1994**

LAB QUESTIONS				NON-LAB QUESTIONS					
<u>Date</u>	<u>n</u>	<u>Mean</u>	<u>S D</u>	<u>n</u>	<u>Mean</u>	<u>S D</u>	<u>t value</u>	<u>p</u>	<u>D F</u>
Jan 90	4	0.609	0.014	48	0.611	0.196	3.812	0.976	50
Jun 90	5	0.41	0.145	47	0.591	0.179	2.776	0.046	50
Jan 91	3	0.604	0.343	49	0.634	0.201	4.303	0.41	50
Jun 91	3	0.709	0.233	49	0.672	0.173	4.303	0.808	50
Jan 92	7	0.574	0.18	45	0.65	0.176	2.365	0.328	50
Jun 92	4	0.483	0.269	48	0.636	0.19	3.182	0.341	50
Jan 93	3	0.468	0.146	49	0.681	0.176	4.303	0.117	50
Jun 93	2	0.723	0.091	50	0.654	0.151	12.706	0.467	50
Jan 94	8	0.607	0.145	44	0.696	0.162	2.365	0.147	50
Jun 94	2	0.793	0.019	50	0.659	0.172	12.706	0.000	50

Table 6: T-test on Provincial Examination Written Section for Overall Means on Lab and Non lab Questions

Lab Questions			Non-lab Questions						
<u>n</u>	<u>Mean</u>	<u>S D</u>	<u>n</u>	<u>Mean</u>	<u>S D</u>	<u>t-calc</u>	<u>t-crit</u>	<u>D F</u>	
6	2.968	0.876	128	4.2	1.946	0.014	1.97	132	

3. Examination of the Biology 11 and 12 Curriculum Guide and IRP

The Biology 11 course is divided into a core curriculum which occupies 70 hours and an options section which requires teachers to choose from 22 topic areas and covers a further 30 hours. On examining the Curriculum Guide it is apparent that for Grade 11, 98% of the laboratory exercises listed are qualitative, leaving only 2% quantitative labs. Analysis reveals also that in the options section, 40% of the labs are confined to two topic areas, viz.

Invertebrate Zoology and Freshwater Biology. If teachers choose not to cover these options then the mean number of labs per optional topic is reduced from 3.238 to 1.7. It is also interesting to note that the percentage of qualitative labs is the same (98%) for the core, optional labs and labs overall.

The Grade 12 course is similarly divided, with a core of 80 hours and an additional 20 hours, choosing two of six optional topics. In Grade 12, as for Grade 11, the number of qualitative labs far exceeds the number of quantitative labs, with 81% qualitative and 11% quantitative. Qualitative labs represent 84% of the core curriculum. There are no quantitative labs listed for the options section, which is surprising when one considers such topics as 'senses' and 'biotechnology' in which there would seem to be plenty of scope for quantitative exercises. In the new Integrated Resource Package, implemented in September, 1996 for Grade 11 and September, 1997 for Grade 12, the situation has been simplified by the removal of all options from the course. The number of quantitative labs increases between Grade 11 and Grade 12 from 15% to 24% and as a fraction of the total number of labs by 31%. Differences between Grade 11 and Grade 12 for other resources, i.e. software, video, laser disc and multimedia are not significant.

A comparison of the Biology 11/12 Curriculum Guide with the Integrated Resource package shows that the number of quantitative labs remains the same for Grade 11 at 3 labs, and increases to seven from six for Grade 12. The number of qualitative labs in Grade 11 is reduced dramatically from 127 to 20, while in Grade 12 the number has decreased from 45 to 22. These reductions are caused by the removal of the options from the courses. There is however, a 71% decrease in qualitative labs for Grade 11 on the core alone and an overall 43% decrease in labs recommended for Grade 12.

Conclusions.

There is little laboratory work being conducted in Biology Grade 11 and 12 classes in British Columbia High Schools. Of the labs that are conducted, the large majority are qualitative, and confirmatory, rather than investigative.

The typical pedagogical pattern of instruction reflects an authoritarian, didactic approach to classroom management. The reason may be that many teachers in their education and training have never encountered a learning experience in which they themselves constructed meaning from the experience of conducting laboratory work.

Instruction has become increasingly textbook-centered. Even though laboratory experiences or demonstrations usually are included, students are rarely encouraged to use scientific methods to solve problems. The laboratory exercises are primarily descriptive in nature and require little analysis or synthesis on the part of the student. Almost all reports on the conditions of teaching and learning in schools calls for, more active learning for students and less passivity; more hands-on, direct opportunities to 'make meaning'.

It is apparent from this research that the philosophies and the goals listed in various Ministry documents, while admirable in concept, are not being accomplished in the practice of

teaching Biology at the senior high school level in British Columbia. At the beginning of the Grade 11 course outline there are 12 laboratory exercises recommended which deal with such topics as: formulating hypotheses, making data tables, control and experimental treatments, devising experiments, reporting results, using models to explain ideas, drawing inferences from data and the Chi-Square test of significance. I suspect that few, if any of these fundamental lab exercises are undertaken on a regular basis. The IRP makes no mention of the 'scientific method' "per se", in the prescribed learning outcomes, but it is covered in the introduction, in a philosophical statement to teachers. A thorough examination of the 'Suggested Instructional Strategies' has not been conducted but a superficial survey indicates that the concept of scientific method is not emphasized.

The quantity and quality of lab work undertaken by Grade 12 students appears to have no effect on the scores overall, on either the Provincial or Scholarship examinations, in that there was no difference in mean scores between lab and non-lab questions. However, results on Provincials show that 62.3% are at a satisfactory or fail level.

Lack of time is a frequently mentioned obstacle to teaching an inquiry-based course and this is compounded by a tendency for teachers to feel that there is a requirement to 'cover the course', particularly at the Grade 12 level, because of the pressure of an external examination.

Very little technology is being used in the teaching of Biology 11 and 12. It would appear that videotapes are the primary supporting technology. There is no convincing evidence of the use of other technologies at significant levels. No schools reported using computer-based data collection.

Assessment techniques are very limited and confined almost exclusively to paper and pencil, recall type tests. The assessment strategy may end up being the key to the degree to which an activity-based or constructivist approach is implemented at the senior level. In particular, the provincial examination, in its present form, would appear to very limited in the variety of assessment strategies utilized.

In summary, the solution involves a complex of changes. A simple change to a constructivist /activity-oriented approach will not effect any real change. It requires a simultaneous change in assessment strategy, hands-on professional development and equally important, a change in expected outcomes for the course. In addition, curriculum reformers of the 90's seem united on the necessity of reducing basic coverage in textbooks and curriculum guides, (Culotta, 1990) - the 'less is more' belief. However, difficulties seem to arise in deciding what should be included and what should be omitted, and for what levels of education, (Yager, 1992).

Recommendations

- More research on high school level laboratory experiences should be encouraged.
- Increased use of technology in the science curriculum. This includes all aspects of technology but in particular, the techniques for direct computer-based telemetry need to be developed and integrated into science programs.
- The provincial examination does not test scientific process and needs to be re-examined. Greater emphasis should be placed on questions requiring more critical thinking and data analysis.
- Resources need to be developed which allow students the opportunity to engage in scientific thinking and participate in scientific inquiry by learning to pose questions,

formulate hypotheses, identify variables, identify experimental controls, and design experiments.

- A full examination of assessment techniques, especially performance based assessment, needs to be undertaken. This was outside the scope of this study, but it is encouraging to see the range of recommended assessment strategies in the IRP for Biology and a move closer to authentic assessment, in addition to paper and pencil tests.
- teachers need much more assistance, professional development, and direct instruction by example, in inquiry-oriented pedagogy rather than the transmission oriented pedagogy prevalent in many professional programs.

References

Hurd, P.D., Bybee, R.W., Kahle, J.B., & Yager, R.E. (1980). Biology Education in Secondary Schools of the United States. *American Biology Teacher*, 42 (7), 388-410

Lehman, J.R. (1989). Chemistry Teachers and Chemistry Students' perceived Advantages and Disadvantages of High School Chemistry Laboratories. *School Science and Mathematics*, 89 (6), 510-514

Levin, B. (1995). Reforming Secondary Education. *Canadian Journal of Educational Administration and Policy*, Number 1

Miller, K.W. (1995). Paradigmatic School Philosophies as barriers to School Reform: A contrast is presented between two models of teaching and learning. In: *Science Educator Abstracts*, 5 (5)

Ministry of Education. (1989). *Year 2000: A Curriculum and Assessment Frame work for the Future*. Victoria: Province of British Columbia.

Ministry of Education (1990). Biology 11 /12 Curriculum Guide. Publication Number CG 0072, Victoria. Province of British Columbia.

Ministry of Education (1991). Science in British Columbia. Publication Number FCG 185. Victoria. Province of British Columbia.

Ministry of Education (1996). Biology 11 and 12: Integrated Resource Package. Victoria. Province of British Columbia

National Committee on Science Education Standards and Assessment (1992). *National Science Education Standards: A sampler*. Washington, DC. National Research Council

Prather, J.P. (1993). Reform revisited: The trend towards constructivist learning. *Journal of Elementary Science Education*, 5 (2), 52-70

Speece, S.P. (1996). Life Science Standards and Curriculum Development for K-12. *The American Biology Teacher*, 58 (4), 206-210

Sullivan, B.M. (1988). A legacy for learners: The Report of the Royal Commission on Education. Victoria. Province of British Columbia.

Tamir, P. (1989). Training Teachers to Teach Effectively in the Laboratory. *Science Teacher Education*, 73(1), 59-69

Tobin, K. (1990). Research on Science laboratory activities: in pursuit of better questions and answers to improve learning. *School Science and Mathematics*, 10 (5), 403-418